IS THE UNIVERSE A WHITE-HOLE?

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Abstract

Pathria(1972) has shown, for a pressureless closed Universe, that it is inside a black (or white) hole. We show now, that the Universe with a cosmic pressure obeying Einstein's field equations, can be inside a white-hole. In the closed case, a positive cosmological constant does the job; for the flat and open cases, the condition we find is not verified for the very early Universe, but with the growth of the scale-factor, the condition will be certainly fulfilled for a positive cosmological constant, after some time. We associate the absolute temperature of the Universe, with the temperature of the corresponding white-hole.

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I. Introduction

The contents of this paper, submitted first in 24 May, 2006, to a journal, is based on a method published by Gomide and Berman(1987); we are not sure that since 1987, the present calculation has not been published by someone else.

Pathria(1972) published a paper showing that, for certain values of the cosmological constant, a pressureless finite (positively curved) Universe could be inside a white-hole, if it obeyed Robertson-Walker's metric (with $k = 1$):

$$ds^2 = dt^2 - \frac{R^2(t)}{\left[1+\left(\frac{kr^2}{4}\right)\right]^2}d\sigma^2 \qquad , \qquad (1)$$

where,

$$d\sigma^2 = dx^2 + dy^2 + dz^2 \qquad . \qquad (2)$$

If R stands for the radius of a "large sphere" of mass M, while G stands for Newton's gravitational constant, a white-hole could be described by the condition that R is smaller than its Schwarzschild's radius:

$$R < 2GM \qquad . \qquad (3)$$

It is known, on experimental grounds, that the present Universe, obeys the Machian relation by Brans and Dicke(1961),

$$R \sim GM \qquad . \qquad (4)$$

We, thus, can think that the Universe may be inside a white-hole, but this should be analyzed by means of Einstein's field equations for the above metric,

$$\kappa\rho = 3H^2 + \frac{3k}{R^2} + \Lambda \qquad , \qquad (5)$$

$$\kappa p = -2\frac{\ddot{R}}{R} - H^2 - \frac{k}{R^2} - \Lambda \qquad , \qquad (6)$$

where,

$$H = \frac{\dot{R}}{R} \qquad ,$$

and,

$$\kappa = 8\pi G \qquad .$$

We study below, all three tricurvature cases ($k = 0, \pm 1$). We also treat the absolute temperature of black holes and the Universe.

Berman(2006;2006a) has studied the same subject by means of Mach's Principle, and the hypothesis of a zero-total-energy for the Universe.

II. Closed Universe as a White-hole

Considering a positive cosmological constant ($\Lambda > 0$), and remembering that the volume V , for a closed Robertson-Walker's Universe, is given by(Adler, Bazin and Schiffer, 1975):

$$V = 2\pi^2 R^3 \qquad , \qquad (7)$$

we find,

$$\rho = \frac{M}{2\pi^2 R^3} \qquad . \qquad (8)$$

From equation(5) we find:

$$\kappa\rho = \frac{3\left[1+\dot{R}^2\right]}{R^2} + \Lambda = \frac{\kappa M}{2\pi^2 R^3} = \frac{2r}{\pi R^3} \qquad , \qquad (9)$$

where r stands for Schwarzschild's radius, i.e.,

$$r = 2GM = R\left\{\frac{\pi}{2}\left[3\dot{R}^2 + 3 + \Lambda R^2\right]\right\} > R \qquad . \qquad (10)$$

Because $\dot{R}^2 > 0$ because $R(t)$ is a real number, we find,

$$\Lambda > \left[\frac{2}{\pi} - 3\right] R^{-2} > -3R^{-2} \qquad . \qquad (11)$$

As the scale-factor is essentially positive, condition (11) will be certainly fulfilled by the condition, $\Lambda > 0$.

We have shown that a closed Universe, while cosmic pressure p follows Einstein's field equation (6) normally, shall be inside a white-hole, if $\Lambda > 0$.

III. Flat Universe as a White-hole

We shall now apply Einstein's field equations for $k = 0$. With the prescription:

$$V = \frac{4}{3}\pi R^3 \qquad , \qquad (12)$$

so that,

$$\rho = \frac{3M}{4\pi R^3} \qquad , \qquad (13)$$

we would find,

$$r = R^3 \left[H^2 + \frac{\Lambda}{3} \right] = R \left[\dot{R}^2 + \frac{\Lambda}{3}R^2 \right] \qquad . \qquad (14)$$

We find that a sufficient condition for $r > R$ is,

$$\Lambda > \frac{3}{R^2} \qquad . \qquad (15)$$

We remark that this condition is equivalent to "closing" the Universe, in what respects the density field equation (but not in terms of the pressure equation). Even if this condition may not prevail for the very early Universe, nevertheless, with increasing values of the scale-factor, eventually the condition (15) shall be fulfilled.

The limiting scale-factor, is of course,

$$R > R_0 = \sqrt{\frac{3}{\Lambda}} \qquad . \qquad (16)$$

IV. Absolute temperature in Cosmology and White-holes

Hawking(2001), cites the formula he obtained many years ago, for the absolute temperature T associated with a non rotating and non charged black-hole; though in our paper we are dealing with Classical Physics, and Hawking's formula is based on Quantum theory, it will be seen that we can make a bridge with Classical Cosmology:

$$T = \frac{\bar{h}\,c^3}{8\pi k R_S} \qquad\qquad , \qquad\qquad\qquad\qquad (17)$$

where, k , and h stand respectively for Boltzman and Planck constants, and R_S stands for Schwarzschild's radius, in such a way that, if we associate the scale-factor with R_S , then, from (17),

$$T \cong \frac{hc^3}{16\pi^2 k} R^{-1} \qquad\qquad . \qquad\qquad\qquad\qquad (18)$$

This is exactly what we find in standard Cosmology, between the scale factor $R(t)$ and T . This is a most striking analogy that points out to a possible white-hole Universe. However, Berman(2006 b; 2007), found that, either for the Machian Universe, or for a 4-D black hole, the entropy is given by the same formula, i.e.,

$$S \propto R^{3/2} \qquad ,$$

provided that, the scale factor and Schwarzschild's radius, obey the condition,

$$R \propto T^{-2} \qquad .$$

The above condition, for the temperature, is a Machian Universe property (Berman, 2006 b, 2007).

V. Open Universe as a white-hole

We shall leave, once more, the cosmic pressure to obey freely Einstein's field equations. From the energy density ρ – equation (5), with $k = -1$, we have, then,

$$r = R \left[\frac{\alpha}{4\pi} \left(3R^2 H^2 + \Lambda R^2 - 3 \right) \right] \qquad\qquad , \qquad\qquad (19)$$

where we suppose, quite generally, that the tridimensional volume is given by:

$$V = \alpha R^3 \qquad\qquad (\ \alpha = \text{positive constant} \ ) \qquad . \qquad (20)$$

The condition for the open Universe to be or become a white-hole, is given by $r > R$, so that,

$$\Lambda > \left[m - 3\dot{R}^2 \right] R^{-2} \qquad\qquad , \qquad\qquad\qquad (21)$$

where,

$$m = 3 + \frac{4\pi}{\alpha} > 3 \qquad . \qquad (22)$$

We conclude that the condition (21) can be staten as,

$$\Lambda > \left[3(1 - \dot{R}^2) \right] R^{-2} \qquad . \qquad (23)$$

At least, we can impose the following sufficient condition:

$$\Lambda > 3R^{-2} > 0 \qquad , \qquad (24)$$

because $\dot{R}^2 > 0$.

By the same token as in last paragraph of Section III above, for the expanding Universe, when the scale factor becomes larger than $\sqrt{\frac{3}{\Lambda}}$ we shall have a white-hole-Universe.

We remark that condition (24) is identical with (16), which refers to a flat Robertson-Walker's metric.

VI. Conclusions

We have shown, in a different context than in Pathria's paper (where $p = 0$, and Λ obeys certain conditions), that the closed Robertson-Walker's Universe, with any value of p constrained to obey Einstein's field equations may be thought as being a white-hole. Brans-Dicke relation to the problem is not conclusive, because it represents only a Machian condition for the Universe. In a similar way, flat or open Universes, in the expanding phase, may become white-holes after R becoming larger than $\sqrt{\frac{3}{\Lambda}}$. Finally, we motivate the analogy between the Universe and a white-hole, by means of their absolute temperatures. The Machian condition for the Universe, was taken, partially, as implying that the absolute temperature ran like $\left(\sqrt{R} \right)^{-1}$. (Berman, 2006 b, 2007) . The standard condition, however, is that $T \propto R^{-1}$, like we considered above.

Acknowledgements

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